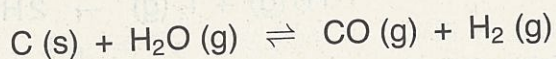


SELF-TEST

A. Multiple Choice:

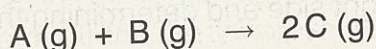
1. For the following system at equilibrium



increasing the volume of the container

- a. forms more C (s).
- b. forms more CO (g) and H₂ (g).
- c. has no effect on equilibrium.

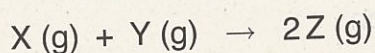
2. For the reaction



K is 9.0 at 35°C. The original partial pressures of the species are: P_A = 0.2 atm, P_B = 0.4 atm, and P_C = 0.15 atm. Which of the following statements is true?

- a. The reaction will move to the left to achieve equilibrium.
- b. The reaction will move to the right to achieve equilibrium.
- c. The mixture of gases is at equilibrium.
- d. The mixture cannot achieve equilibrium unless more gas is added.

3. The exothermic reaction

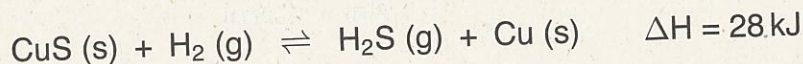


reaches equilibrium at 200°C. How many of the following statements are true?

- If the mixture is transferred to a reaction flask of twice the volume, the amount of products and reactants will not change.
- Addition of an appropriate catalyst will result in the formation of a greater amount of Z (g).
- Lowering the temperature to 100°C will increase the amount of Z (g).
- Addition of helium will have little or no effect on the amount of Z (g) obtained.

- a. 0 b. 1 c. 2 d. 3 e. 4

4. How is the following equilibrium shifted by cooling?



- a. Hydrogen sulfide gas is formed.
- b. Hydrogen sulfide gas is consumed.
- c. There is no change.

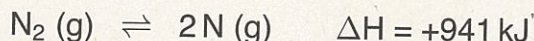
5. Three chemical systems are each in equilibrium.

- (1) $2\text{CO (g)} + \text{O}_2 \text{ (g)} \rightleftharpoons 2\text{CO}_2 \text{ (g)}$
- (2) $\text{H}_2 \text{ (g)} + \text{Cl}_2 \text{ (g)} \rightleftharpoons 2\text{HCl (g)}$
- (3) $2\text{HI (g)} \rightleftharpoons \text{H}_2 \text{ (g)} + \text{I}_2 \text{ (s)}$

The pressure on each of these systems is increased so that the volume decreases from 20 L to 10 L. The equilibrium shift is correctly represented as

- | | | |
|------------------|---------------|---------------|
| a. (1) → | (2) → | (3) no change |
| b. (1) no change | (2) ← | (3) ← |
| c. (1) → | (2) no change | (3) → |
| d. (1) ← | (2) → | (3) no change |
| e. (1) → | (2) no change | (3) no change |

6. The gaseous reaction



is in equilibrium at 1200 K. Which of the following operations will increase the value of the equilibrium constant, K?

- (1) Addition of nitrogen (N_2) gas
 (2) Increasing the temperature
 (3) Increasing the pressure

- a. (1) b. (2),(3) c. (1),(3) d. (2) e. (3) e. none of those

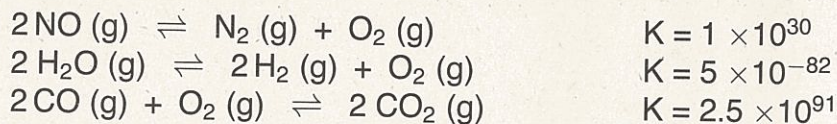
7. For the reaction



K is 1.0 at 500°C. The original partial pressures of the species at 500°C are: $P_A = P_B = P_C = 0.2 \text{ atm}$. Which of the following statements is true?

- a. The partial pressure of A will increase as equilibrium is reached.
 b. The partial pressure of B will increase as equilibrium is reached.
 c. The partial pressure of C will increase as equilibrium is reached.
 d. The system is already at equilibrium.
 e. None of the above statements represents reality.

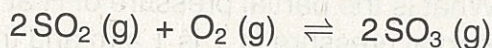
8. At 25°C



The compound most likely to dissociate and give $\text{O}_2(\text{g})$ at 25°C is

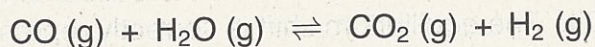
- a. NO b. H_2O c. CO_2 d. CO

9. What is the equilibrium expression for the following reaction?



- | | | |
|---|---|--|
| a. $\frac{(P_{\text{SO}_3})^2}{(P_{\text{SO}_2})^2 (P_{\text{O}_2})}$ | b. $\frac{(P_{\text{SO}_3})^2}{(P_{\text{SO}_2})^2 + (P_{\text{O}_2})}$ | c. $\frac{2(P_{\text{SO}_3})}{2(P_{\text{SO}_2})(P_{\text{O}_2})}$ |
| d. $\frac{(P_{\text{SO}_2})^2 (P_{\text{O}_2})}{(P_{\text{SO}_3})^2}$ | e. $\frac{4(P_{\text{SO}_3})^2}{(P_{\text{SO}_2})^2 (P_{\text{O}_2})}$ | |

10. For the reaction

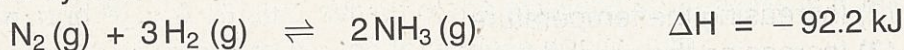


K is 1.00 at about 1100 K. Which one of the following statements must always be true concerning this reaction at equilibrium?

- a. $P_{\text{CO}} = P_{\text{H}_2\text{O}} = P_{\text{CO}_2} = P_{\text{H}_2}$
 b. $P_{\text{CO}} \times P_{\text{H}_2\text{O}} = P_{\text{CO}_2} \times P_{\text{H}_2}$
 c. $P_{\text{CO}} = P_{\text{H}_2\text{O}}$ and $P_{\text{CO}_2} = P_{\text{H}_2}$
 d. $P_{\text{CO}} \times P_{\text{H}_2\text{O}} = P_{\text{CO}_2} \times P_{\text{H}_2} = 1.00$
 e. All of the above are true.

B. Circle the correct answer:

Consider the system



Show the effect on the partial pressure of H_2 and on the numerical value of K by circling the letters *D* for a decrease, *I* for an increase and *NC* for no change.

	P_{H_2}			K		
1. adding NH_3	D	I	NC	D	I	NC
2. doubling the volume	D	I	NC	D	I	NC
3. increasing T	D	I	NC	D	I	NC
4. adding Ar (g)	D	I	NC	D	I	NC
5. adding $\text{N}_2 \text{ (g)}$	D	I	NC	D	I	NC

C. Fill in the blanks:

The following questions are about the following hypothetical reaction:

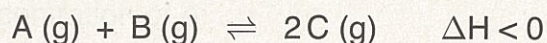


- _____ 1. What is the partial pressure of R at equilibrium if the equilibrium partial pressure of T is 1 atm and that of U is 2 atm.
- _____ 2. In which direction will the reaction proceed (\rightarrow , \leftarrow , or no change) if the volume of S is doubled?
- _____ 3. It is determined that K increases when the temperature is increased. What is the sign of ΔH° for the reaction?

- _____ 4. In which direction will the reaction proceed if $Q = 2$?
(\rightarrow , \leftarrow , can't tell)
- _____ 5. What is K (equilibrium constant) at the same temperature if the pressure of R is doubled from 1 atm to 2 atm?

D. Problems:

Consider the hypothetical reaction



1. Write the equilibrium expression for the reaction.
2. Calculate K at a certain temperature if $P_A = 0.250$ atm, $P_B = 0.135$ atm, and $P_C = 0.500$ atm.
3. For another temperature, calculate K if we start with a 5.00-liter flask in which $P_A = 0.300$ atm and $P_B = 0.750$ atm. At equilibrium, 25.0% of A has been used up.

4. If K for the reaction at 100°C is 50.0, and we start with a 1.00-L flask where:

$$P_A = P_B = 0.250 \text{ atm, and } P_C = 0.500 \text{ atm}$$

a. Determine the direction of the reaction.

b. Calculate the partial pressures at equilibrium of A, B, and C at 100°C .

c. After equilibrium has been reached, the pressure of C is temporarily increased to 1.500 atm. Calculate the partial pressures of A, B, and C after equilibrium has been reestablished.

5. State in which direction the equilibrium will shift to relieve the following stresses on the system.
- Increase T.
 - Increase V.
 - Add Ar.
 - Increase the concentration of A.
6. Recall that K is 50.0 at 100°C. At 23°C, K is 137. What is ΔH° for the forward reaction?

ANSWERS**Exercises:**

$$(E1) K = \frac{(P_{NO})^4 (P_{H_2O})^6}{(P_{NH_3})^4 (P_{O_2})^5}$$

$$(E2) K = (P_{NO_2})^2 (P_{O_2})^{\frac{1}{2}}$$

$$(E3) 2.0 \times 10^1$$

$$(E4) NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g); \quad K = (P_{NH_3})(P_{HCl}); \quad K = 0.544$$

$$(E5) 0.953$$

$$(E6) 0.522$$

$$(E7) \text{left to right (} \rightarrow \text{)}$$

$$(E8) 2.1 \text{ mg}$$

$$(E9) P_{H_2} = P_{CO_2} = 0.13 \text{ atm}; \quad P_{CO} = 0.12 \text{ atm}; \quad P_{H_2O} = 0.22 \text{ atm}$$

$$(E10) \text{a. } \rightarrow \quad \text{b. } \leftarrow \quad \text{c. } \leftarrow \quad \text{d. } \rightarrow \quad \text{e. } \rightarrow$$

$$(E11) P_{H_2} = 0.619 \text{ atm}; \quad P_{CO_2} = 0.219 \text{ atm}; \quad P_{CO} = 0.281 \text{ atm}; \quad P_{H_2O} = 0.481 \text{ atm}$$

$$(E12) 953 K$$

Self-Test

A. Multiple Choice:

- | | | | | |
|------|------|------|------|-------|
| 1. b | 2. b | 3. d | 4. b | 5. c |
| 6. d | 7. d | 8. a | 9. a | 10. b |

B. Circle the correct answer:

- | | | | | |
|---------|---------|--------|----------|---------|
| 1. I NC | 2. I NC | 3. I D | 4. NC NC | 5. D NC |
|---------|---------|--------|----------|---------|

C. Fill in the blanks:

- | | | | | |
|----------|--------------|------|------|------|
| 1. 2 atm | 2. no change | 3. + | 4. ← | 5. 1 |
|----------|--------------|------|------|------|

D. Problems:

1. $K = \frac{(P_C)^2}{(P_A)(P_B)}$

2. 7.41

3. 0.148

4a. Reaction goes to the right

4b. $P_A = P_B = 0.110$ atm; $P_C = 0.780$ atm

4c. $P_A = P_B = 0.190$ atm; $P_C = 1.341$ atm

5a. ←

b. no change

c. no change

d. →

6. -12.0 kJ